Drought Assessment in Nestos River Basin (N. Greece) for the Period 1955-2018

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Abstract

Drought is a significant meteorological phenomenon that can seriously impact natural ecosystems. Drought assessment and monitoring should be continuous in regions of high ecological importance, for the conservation of natural vegetation distribution and dynamics. In this study, we analyzed monthly precipitation data obtained from five meteorological stations in the Nestos' river sub-basin in Greece in order to detect drought episodes during the period 1955-2018 by employing the Standardized Precipitation Index (SPI). The results indicate that the coastal and altitudinal lower areas of the region faced more frequent and more severe drought events during the recent years compared to the past, whereas the climatic conditions in the mountainous areas are more favorable. The hydrological years 1977-1978, 1984-1985, 1988-1989, 1998-1999 and 1999-2000 were the years of the most severe droughts in the basin. From the trend analysis of the SPI it appears that the lower part of the sub-basin is anticipated to face even more droughts in the future. These patterns may have significant impacts on the natural rainfed vegetation, especially at the river's Delta where habitat types of high priority are located. Thus, the need to adopt measures for the conservation of the local ecosystem is critical, considering also that the local habitat types are characterized by high demands for water availability.

Keywords

SPI, drought, Nestos, Mesta, trends, Mann-Kendall, Sen slope, DrinC software

1. Introduction

The Mediterranean basin includes diverse types of habitats and it is considered a biodiversity hotspot [1,2], due to the combination of climate conditions and the variety of geographical and topographical features of the region. Climate shifts and extreme events, such as droughts, in this area may lead to alterations of the ecological balance and cause pressures to human activities. Many studies have identified trends, especially in precipitation timeseries [3-9], as well as in drought patterns [10-13], indicating a tendency to drier conditions [14,15] in various areas within the Mediterranean region. The efficient management of drought risks is essential for compensating the impacts of droughts on several sectors, including the economy, the societies and the environment. To this end, proper understanding, identification and monitoring of drought characteristics is essential, especially in economically and ecologically important and vulnerable regions. Additionally, year to year drought conditions is critical

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to be monitored for assessing the effects on the sustainability of the natural rainfed ecosystems [16], as decreased precipitation and droughts have a strong impact on plants' growth dynamics [17,18].

Nestos is a transboundary river, shared between Bulgaria and Greece. The river delta, which is located in the Greek sub-basin, is considered as of high ecological significance. Many parts of the basin, including Nestos' Delta, have been declared as Natura 2000 protected sites. Especially the river's Delta hosts a variety of priority habitats that require high water availability in order to be sustainable. Therefore, drought monitoring is crucial in this region, considering also that the hydrological regime of Nestos river is rather sensitive to drought episodes [19]. Furthermore, drought analyses using proper tools, such as drought indices, is important for indicating appropriate management measures in transboundary rivers [20].

The present study is based on previous studies by Proutsos et al. [21,22] that analyzed the precipitation trends in the Greek part of Nestos river and assessed the changes occurred since the 1950s. In this work, the drought conditions of this region are evaluated, analyzing the annual changes of the SPI drought index and assessing the spatial variability in the basin.

2. Study Site and Climatic Data

The geophysical pattern of the study area, which includes the Greek sub-basin of Nestos river, is presented in Figure 1. Details about the characteristics and information concerning the high ecological importance of the area can be found in Proutsos et al. [21-23].

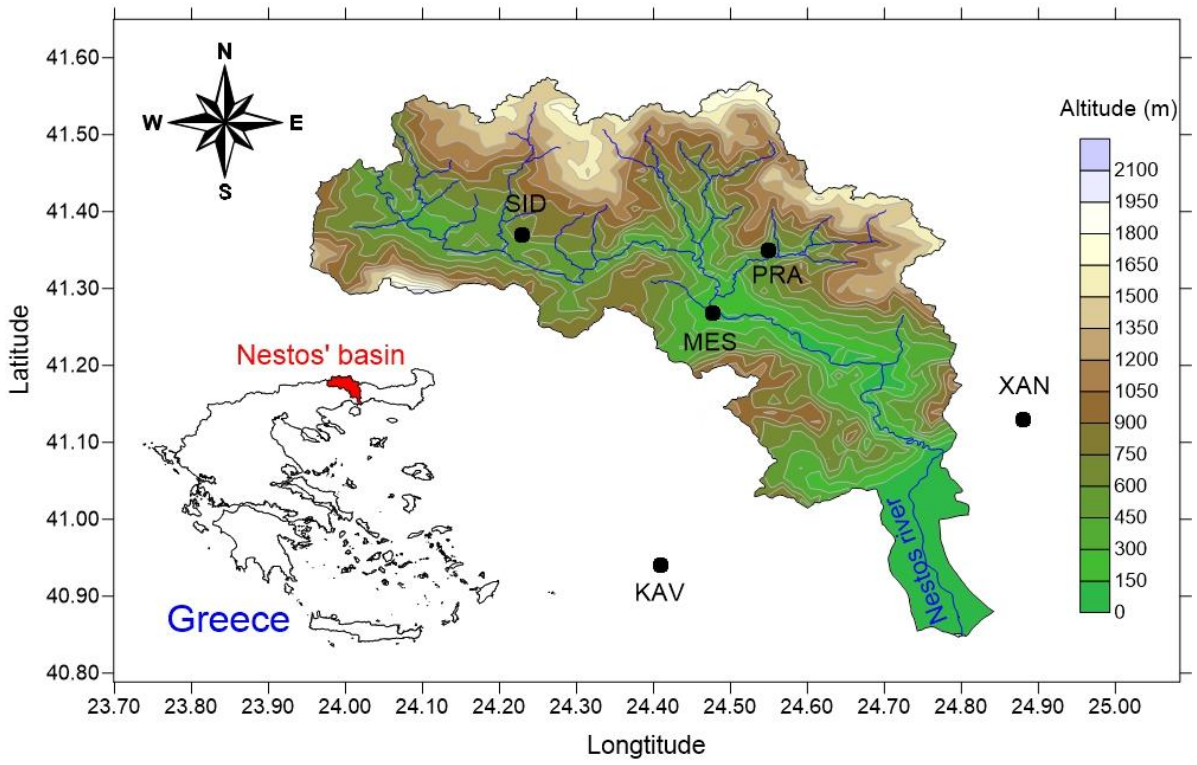

Figure 1: Geophysical map of the Nestos' sub-basin (Greece) along with the positions of the five long-operating meteorological stations.

The climate of the area is humid [15,24] according to UNEP's [25] aridity classification system based on Thornthwaite's [26] water balance approach, whereas the recent precipitation trends [21,22] indicate significant reduction in the coastal areas of the region, but also precipitation increase in the mountainous part of the basin with high seasonal variability [21]. The changing trends are more rapid at the current climatic period [22].

In this work, we assessed the drought conditions for the Greek part of the basin. Monthly precipitation data series, obtained from five long-operating meteorological stations, were analyzed for the period 1955-2018, on a hydrological year basis. The specific characteristics of the meteorological

stations are presented in Table 1. The drought assessment was performed by employing the widely used Standardized Precipitation Index (SPI) [27], using DrinC software [28, 29]. The index is based solely on precipitation data and can be applied for several timesteps. In this study, the annual timestep of the hydrological year (October to September) was adopted, an approach that is considered suitable for assessing drought impacts on water availability [30,31]. SPI values classify the adopted time period of each year to one of the following eight classes (four wet and four dry): extreme drought (SPI≤-2.0), severe drought (-2.0<SPI≤-1.5), moderate drought (-1.5<SPI≤-1.0), mild drought (-1.0<SPI≤-0.5), near normal (-0.5<SPI≤0.5), mildly wet (0.5<SPI≤1.0), moderately wet (1.0<SPI≤1.5), severely wet (1.5<SPI≤2.0), and extremely wet (SPI>2.0).

Table 1
Meteorological stations' characteristics

Code	Site name	Longitude	Latitude	Altitude	Operating period	Owner
KAV	Kavala	24.41°E	40.94°N	5 m	1986-2004 (n=19)	HNMS
MES	Mesochori	24.47°E	41.27°N	120 m	1963-2018 (n=56)	DEH
PRA	Prasinada	24.55°E	41.35°N	660 m	1962-2018 (n=57)	DEH
SID	Sidironero	24.23°E	41.37°N	570 m	1963-2018 (n=56)	DEH
XAN	Xanthi	24.88°E	41.13°N	83 m	1955-2011 (n=57)	HNMS

To detect possible trends of the annual SPI, the Mann-Kendall test was applied [32,33] and the trend slopes were estimated by the Sen's slope method [34]. These methods are widely used and are considered reliable in hydrological and climatic trend analysis [6,21,35-37]. For the trend detections, the evaluation of their significance and the calculation of their magnitudes, the MAKESENS 1.0 software was applied [38]. The spatial patterns presented in this work were developed by the application of the Kriging's interpolation technique, where the unknown SPI slope values at all points across a defined spatial domain are estimated using a weighted average of all known values around the point [39].

3. Results and Discussion

The annual values of the SPI, based on the precipitation data of the five meteorological stations, are presented in Figure 2. The annual SPIs clearly indicate that the altitudinal lower coastal areas (KAV and XAN stations) of the region, located at the lower part of the basin, experience more intense and more frequent extreme or severe drought events during the recent years (after 1990). On the contrary, at the altitudinal higher positions (MES and PRA stations) the drought events were more frequent and intense in the previous decade (1980s), whereas at the mountainous areas (SID station) no extreme droughts were detected.

More specifically, for KAV station, 1998-1999 and 2003-2004 were hydrological years of extreme drought, 1996-1997 and 2001-2002 years of severe drought and 1994-1995, 1995-1996, 1997-1998, 2000-2001 and 2002-2003 years of moderate drought. The most severe drought in KAV occurred in 1998-1999, when SPI was -2.2.

XAN faced no extreme drought events, however 1998-1999, 1999-2000 and 2001-2002 were years of severe droughts. The most severe drought year was 1999-2000 (SPI=-1.8).

In MES and PRA, 1984-1985 and 1988-1989 were extreme drought years. Severe droughts were recorded in 1973-1974 and 1992-1993 and moderate droughts in 1989-1990, 1993-1994 and 2016-2017 for PRA station. Also, moderate drought was identified during the years 1967-1968, 1986-1987, 1989-1990, 1991-1992, 1992-1993, 1993-1994 and 2000-2001 for MES station. The most extreme drought years were 1988-1989 for MES (SPI=-2.3) and 1984-1985 for PRA (SPI=-2.5).

For SID station, no extreme droughts were identified. However, 1977-1978, 1980-1981 and 1992-1993 were years of severe drought and 1975-1976, 1976-1977, 1984-1985 and 1991-1992, were years of moderate drought. With regard to the available data, 1977-1978 was the year with the most stressful conditions (SPI=-1.7).

Considering the years with the highest negative values in each station, i.e. 1998-1999 for KAV,

1999-2000 for XAN, 1988-1989 for MES, 1984-1985 for PRA and 1977-1978 for SID, the spatial patterns of Figure 3 were produced. These patterns confirm that in the recent years the coastal areas of the basin faced drier conditions compared to the past, whereas the mountainous regions faced more severe drought events in the past, but not during the recent years.

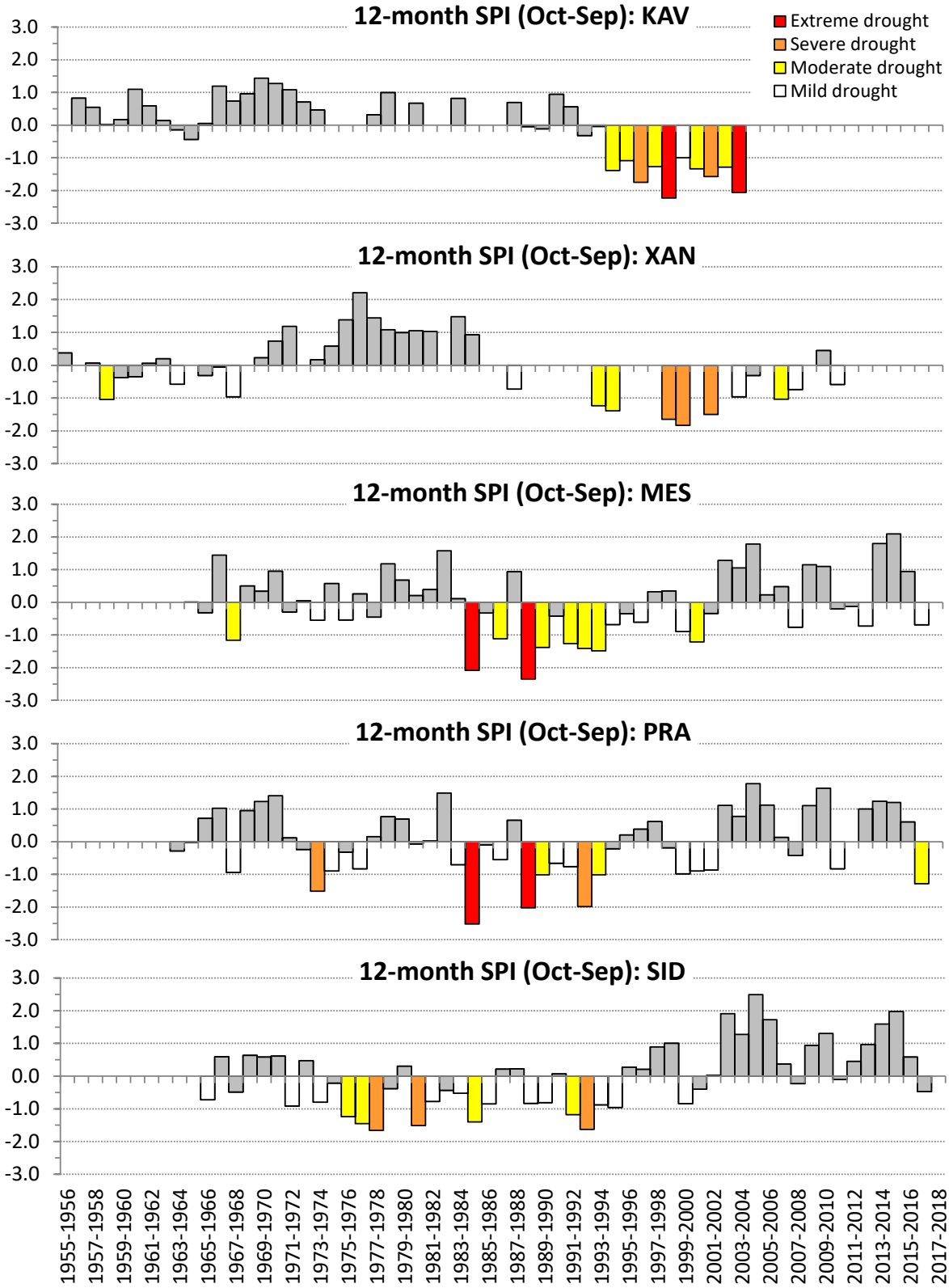

Figure 2: Annual values of the SPI index for the operating period of the five meteorological stations in Nestos' river sub-basin.

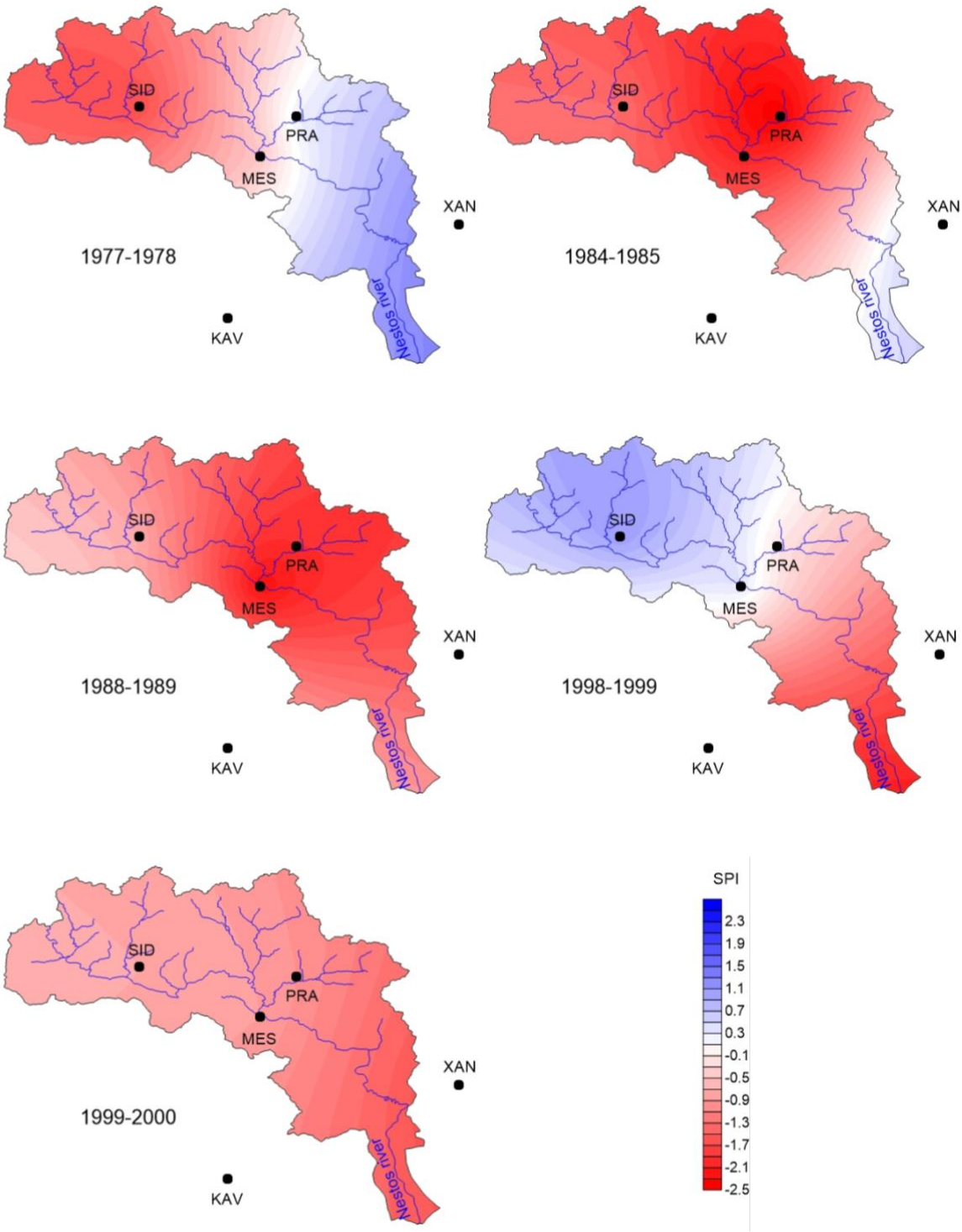

Figure 3: Spatial distribution of the SPI for specific years with most extreme drought events, identified by the available data from the five meteorological stations.

The trend analysis of the SPI values produced the pattern depicted in Figure 4, which indicates that SPI presents negative and strong decreasing trends in the low altitude coastal areas, whereas at the mountainous areas of the basin the conditions are more wet, however these latest positive trends are not significant. These changes are anticipated to cause problem to the local high priority habitats that are located at the lower part of the basin, since they are highly vulnerable in the changes of precipitation. Such high water demanding ecosystems, are considered of high risk and require interventions to ensure that they have the necessary water quantities in order to be sustained.

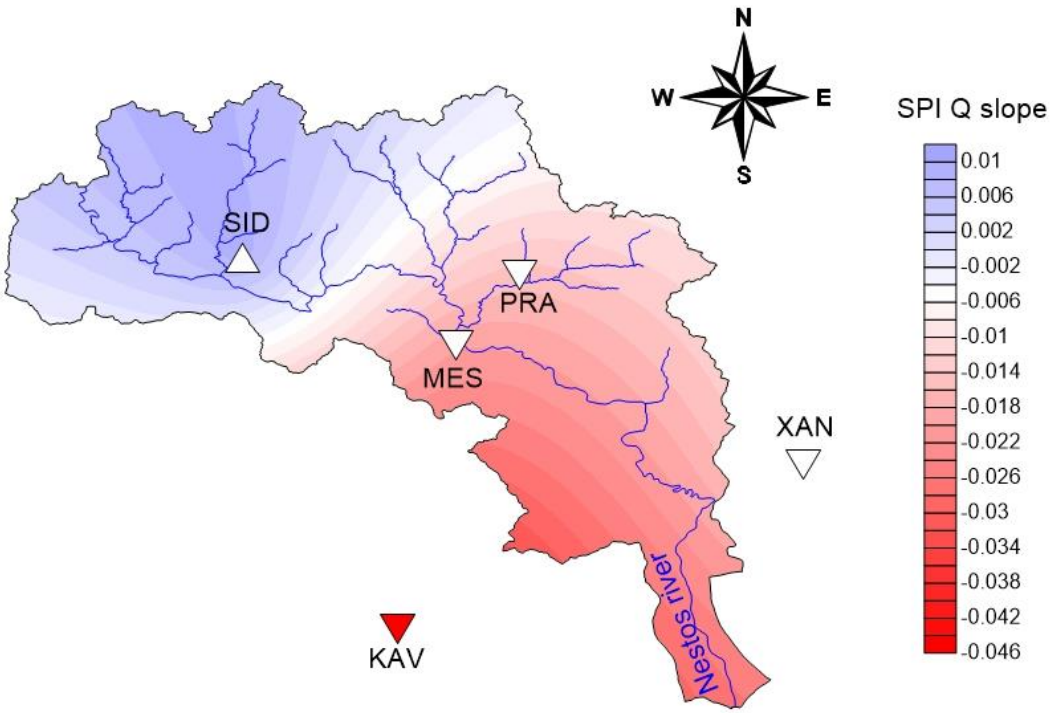

Figure 4: Changing trends of the SPI index with time. Q, is the changing rate of the index in y-1, whereas the direction of the white triangles in each station indicates if the trend is either positive or negative but in all cases the trend is not significant at a=0.10. The red triangle indicate negative and strong trend at a=0.001.

4. Conclusions

In this work, a drought assessment was performed for the Nestos' river sub-basin in N. Greece. The region hosts a variety of significant habitats that require high water availability in order to be preserved. The precipitation changes can highly affect the vegetation patterns in the region, thus the continuous monitoring of drought is necessary. From the results of this study, it is indicated that the altitudinal lower coastal part of the basin is at high risk and faces, in the recent years, more severe and frequent drought events compared to the past. The western coastal areas are even more vulnerable. On the other hand, the climatic conditions appear to be more favorable nowadays, compared to the past, in terms of drought frequency and severity. This is expected to favor the existing mountainous ecosystems. However, specific measures should be undertaken to conserve the highly valuable coastal ecosystem and conserve the priority habits of the coastal zone. Such interventions should be assisted by the operation of the existing uphill dams and impose the continuous co-operation of the stakeholders from Greece and Bulgaria and the implementation of common strategies in order to achieve the ecological goals.

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